[1]S UMMARY REPORT ON KEY ACTS EXPERIMENTS

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ASTRACT

NASA's Advanced Communications Technology Satellite (ACTS) is an on-orbit test bed in geostationary orbit. Launched on September 12, 1993, ACTS is pioneering new technologies that promise to propel communication satellites into new and expanded roles in the National and Global Information Superhighways. Over 100 different industry, government, and university organizations are conducting a variety of user service application, technology verification and propagation experiments. This paper addresses the experiments being conducted using the on-board baseband processor to efficiently route communication traffic to and from small 1.2 meter diameter antenna, T1 VSAT earth stations. These T1 VSATs provide the capability for integrated voice, data, video, multimedia and ISDN traffic to be delivered to/received from multiple destinations in a single hop with throughputs from 64 Kbps up to 1.79 Mbps per earth station.

INTRODUCTION

The Advanced Communications Technology Satellite Program continues NASA's proud tradition of pioneering new and innovative advances in communication satellites. ACTS, as the blueprint for future communication satellites, is an on-orbit test bed in geostationary orbit operating in the Ka frequency band (30/20GHz). ACTS is pioneering dynamic hopping spot beams and advanced on-board traffic switching and processing. These advanced technologies permit on-demand allocation of satellite channels, frequency reuse and smaller earth stations for direct to user interconnectiivty. The ACTS system provides user data rates from a few kilobits per second to 622 megabits per second. The commercial adaptation of these technologies promises to propel communication satellites into new and expanded roles in the National and Global Information Infrastructure. User trials with the ACTS test network are validating the all digital, on-demand, high bandwidth, integrated video, data, voice and multimedia applications needed for new, innovative and more cost effective user services.

ACTS Experiments Program

The validation of the ACTS technologies and the investigation of new and innovative user service applications is being accomplished through the ACTS Experiments Program. The ACTS flight and ground segments are being made available to industry, government and universities for evaluation, experimentation and demonstrations. A two year period of investigation was initially planned after launch on September 12, 1993 and following a nominal two month period of on-orbit checkout. However, enough stationkeeping fuel is carried on board to provide spacecraft stationkeeping for up to 4.5 years (May 1998)

As of November 1995, over 80 experiments have been approved and almost 60 of these have initiated experiment operations. These experiments involve over 100 different industry, government and university organizations. The ACTS System is operated 24 hours per day, seven days per week in support of experiment operations.

The experiments can be grouped into three major categories to include:

1. Technical Performance Evaluation Experiments.
2. Propagation Measurements.

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3. Application Experiments and Demonstrations

Technology Verification Experiments are being conducted to characterize and validate the on-orbit performance of spacecraft and payload systems, the switching networks and the performance of the various earth stations being used.[1]

Propagation Experiments are being conducted to expand the state of knowledge about the Ka-band frequency impairments to earth-space communications including rain attenuation, the effect of clouds and clear air and tropospheric scintillation. Dynamic effects such as fade duration and fade rates are of particular interest for the design of fade compensation techniques. A thorough characterization of the propagation as well as the testing of the various fade mitigation techniques such as power control and site diversity, is well underway. The ACTS beacons at 20 and 27.5 GHz along with the propagation receive-only terminals are being used to determine the dynamics of fade depths, duration and rates of change as a function of rain and environmental conditions for the rain climate regions of North America.[1]

Application Experiments comprise over half of the experiments being conducted. ACTS is a unique testbed allowing for experimentation with a wide range of user service applications. They involve a variety of mobile, fixed and video broadcast services. These user application investigations for the most part, are designed to provide bandwidth on-demand and to be completely compatible with the terrestrial system. Most of the application experiments are oriented toward services with commercial potential to include medical, business networks, terrestrial network restoral, science networks, integrated services digital network (ISDN), education, DoD tactical video, data, imagery and voice, fixed services and broadcast video, supervisory control and data acquisition (SCADA), seamless high data rate communications compatible with the terrestrial information superhighway and voice and broadband aeronautical mobile.

EXPERIMENT OPERATIONS

The ACTS experiment operations system is shown in figure 1. It is composed of a number of key elements: (1) The ACTS satellite, located in geostationary orbit at 100° west longitude (2) The Satellite Control Center, located at Lockheed Martin Astro Space in East Windsor, New Jersey. This facility controls the spacecraft and provides 24-hour monitoring of the spacecraft health and status. (3) The Telemetry Tracking and Command Station, located at the NASA Lewis Research Center (LeRC) in Cleveland, Ohio. Linked by terrestrial lines with the Lockheed Martin Control Center, this facility uplinks commands and receives telemetry from ACTS at Ka-band. A NASA Master Control Station (MCS), also located at the NASA LeRC, controls the Ka-band communications network and directs all experiments.

Figure 1 also depicts the major type of user trials which are being carried out using the ACTS system. These include:

- T1 VSAT links to customer premises earth station including ISDN capability (1.8 Mbsp)
- Very high data rate (622 Mbps) networks
- Broadband video and high rate data to aircraft
- Voice and low rate data to aircraft
- Terrestrial mobile voice, video, low rate data
- Supervisory Control and Data Acquisition (SCADA) networks (4.8 Kbps)
- Propagation

ACTS EARTH STATIONS

ACTS provides a unique on-orbit platform, allowing for a wide variety of user applications involving data rates from a few kilobits per seconds to hundreds of megabits per second. Figure 2 portrays some of the different earth station types and their digital information data rates. ACTS uses two types of on-board switching to interconnect the multiple spot beams and route signals to their appropriate destinations.[2-4] The baseband processor (BBP) mode uses on-board memory and circuit switching to efficiently route communication traffic from small earth stations. The microwave switch matrix (MSM) mode, a memoryless switch, provides dynamic beam-to-beam routing by using a 3x3 switch configuration and 900 MHz bandwidth channels.

In the BBP mode, the 1.2 meter and 2.4 meter T1 VSATs are providing voice, video, data and multimedia services with throughputs up to 1.79 Mbps per earth station. The NASA Ground Station is located at the Lewis Research Center (LeRC) in Cleveland, Ohio. It uses a 5.5 meter antenna for spacecraft command and control as well as functions as a BBP traffic terminal. It supports traffic from 64 Kbps up to multiple T1 (1.54 Mbps) circuits.

To fully demonstrate the digital switching capability of ACTS, an Integrated Services Digital Network (ISDN) capability has been developed to supplement the basic operation of the T1 VSATs and the NASA Ground Station. A Primary Rate Interface (PRI) provides the ISDN service interface. PRI ISDN has twenty-three, 64 Kbps circuits and a 64 Kbps signaling channel. The ACTS PRI will provide ISDN services compatible with terrestrial ISDN services.

The MSM mode accommodates earth stations operating in the low kilobits per second rate up to hundreds of megabits per second. The 0.3 meter USAT will be used for SCADA applications at 4.8 Kbps as well as video broadcast applications. The mobile terminal, built by JPL, accommodates data rates of 2.4, 4.8, and 9.6 Kbps. Higher data rates at 64 and 128 Kbps can be supported under restrictive link conditions. Advanced, state of the art, proof of concept, Ka-band, Monolithic Microwave Integrated Circuit (MMIC) phased arrays have been developed by both NASA LeRC and U.S. Air Force Rome Labs and their industry partners. Using these phased arrays, an aero mobile terminal was assembled to support duplex data rates at 2.4 and 4.8 Kbps. Larger arrays have been built and are being used to support additional tests on both ground vehicles and aircraft at received data rates up to 386 Kbps. A broadband aero terminal has been developed by JPL using a mechanically steered, slotted waveguide array. This terminal supports data rates from 386 Kbps to 1.54 Mbps.

NASA and ARPA have jointly developed high data rate (HDR) earth stations to exploit the wide bandwidth (900 MHz) capabilities of ACTS. Employing a 3.4 meter antenna, the HDR earth stations provides multiple OC-3 (155 Mbps) or a single OC-12 (622 Mbps) interconnection for point-to-point or point-to-multipoint operations. These earth stations have full duplex capability using satellite switch TDMA and accommodate the SONET protocols.

The Link Evaluation Terminal (LET) is also located at LeRC in Cleveland, Ohio. The LET, using a 4.72 meter antenna, is providing transponder and MSM characterization via loop back communications to perform tests and measurements. In addition, provisions have been incorporated into the LET that allows other experimenters to use the transmitter and receiver chains.

Propagation, receive-only, terminals are being used to monitor the spacecraft beacons at 20.185 and 27.505 GHz. These terminals employ a 1.2 meter antenna with a dual polarized feed. Total power radiometers are also included in the signal path to monitor sky noise at each frequency.

A total of 57 earth stations are being used to support the various experiments being conducted.

Application Experiments

NASA envisioned that future communication satellites would serve a wide range of users to include mobile, fixed and video broadcast services. The ACTS System was designed to provide a test bed whereby application users would have the opportunity to investigate and conduct trials on a wide range of business applications so as to characterize and validate the capability of dynamic hopping beams, on-board switching and processing and the use of Ka frequency band to provide expanded or new and innovative user services in a potentially cost effective manner. One of the goals of the Experiments Program was to conduct a balanced set of experiments and demonstrations that would evaluate voice, video, data and multimedia user services applications enabled by the ACTS technologies, especially those that have commercial potential. Some of the user services that ACTS will furnish are not effectively provided by today's commercial communications satellites on a broad scale. The 57 earth stations developed as part of the ACTS Program allow users to investigate a wide range of land and aeronautical mobile, fixed and video broadcast services as data rates that range from kilobits to megabits per second.

Low Data Rate Application

This paper will review some of the results of applicationsusing the BBP mode of operation and the T1 VSATs. Land and aeronautical mobile experiment using both reflector and phased arrays are discussed in companion papers as well as in a previous conference.[5-8] The USAT trial for SCADA applications is just underway at Southern California Edison [9]. High data rate applications (155 Mbps and 622 Mbps) are covered elsewhere [1,10,11]

T1 VSAT User Applications

In the BBP mode of operation, 19 T1 VSATs provide users with the capability to transmit/receive 1.79 Mbps of digital information in 64 Kbps increments. A versatile user interface designed into the T1 VSAT allows a full range of voice, data, video and multimedia services to be handled. Multiple circuits in increments of 64 Kbps can be set up on-demand and simultaneously transmitted to or received from multiple destination for full mesh interconnectibility. These user services are completely compatible with the terrestrial system. Figure 3 depicts the ACTS satellite/terrestrial test network. Both T1 VSAT (low data rate earth stations) and High Data Rate (HDR) earth station locations are indicated. These spots depict the locations where T1 VSAT & HDR earth station have been, presently or will be located as part of the ACTS Experiments Program. Not shown are the numerous locations where land and aeronautical mobile operation have been conducted. As indicated in this figure, at many of the locations both the T1 VSAT and HDR earth stations have been or are being integrated into the terrestrial network, This seamless satellite-terrestrial interconnectivity provides for the ability to accommodate short duration experiments or demonstrations eliminating the time and expense of moving earth stations. Such satellite/hybrid network interconnections will become key elements of the national and global information superhighway or skyway as those of us in the satellite world like to emphasize.

The next section will review a number of the T1 VSAT user trials that have been conducted to date.

Telemedicine

A number of telemedicine applications have been or will be conducted using ACTS. The need for highly reliable communication links is becoming increasingly important to provide for the delivery of high-quality cost effective medical care. With the growing availability and use of advanced diagnostic instruments such as MRI, CAT and ultrasound, it is becoming essential to be able to transmit and receive data in real time from one medical facility to another to enhance the quality of care, avoid duplication of tests and seek consultation from experts who reside at different medical facilities.

The Mayo Clinic has conducted a number of trials using ACTS. Phase 1 connected St. Elizabeth's Hospital in Wabaska, Minnesota with the Mayo Clinic in Rochester, Minnesota. Phase 2 provided telemedicine consultations between the Mayo Clinic in Rochester and the Indian Health Services Hospital at the Pine Ridge Indian Reservation in South Dakota.

In the phase 1 trials with St. Elizabeth's Hospital, dialysis, speech pathology and teleradiology image transfers were examined. Overall, it was determined that remote dialysis monitoring was feasible and found to be acceptable both by patients and by the health care providers. It was felt that remote dialysis monitoring via communication links could be used for day to day clinical operations. In the speech pathology trials, Mayo observed a 96 percent concurrence regarding speech pathology diagnosis between the on-site clinician and the consulting investigator at Rochester. For these trials follow up interviews with patients, family members or caregivers indicated that they were pleased with the satellite interaction and that the consulting and recommendations provided were useful.

Phase 2 encompassed consultations in 13 medical specialties, physician education programs and training programs for health professionals. Most participants reported that the quality of the T1 (1.54 Mbps) video and audio signals were good and were acceptable for delivery of basic educational and health services. Some 50 different clinical consultations were conducted. The majority of the Pine Ride patients felt that the "remote" consultations had made an important contribution to their health care. More Pine Ridge clinicians than Mayo clinicians concluded that their management of the patient changed as the result of consultation via ACTS. The Pine Ridge clinicians reported that almost half of the changes in their management of patient care were major. Mayo's overall conclusion was that the use of ACTS like technologies for health care delivery is feasible, with a high degree of acceptance on the part of health care providers and patients.

In another telemedicine trial, Krug Life Science, Inc. and the NASA Johnson Space Center (JSC) in Houston, TX, examined patients at the Fitzsimmons Army Medical Center in Boulder, Colorado, using the ACTS T1 VSAT links. Using a portable, high resolution retinal imaging camera, Houston specialists examined live color images of the retinas of patients in Boulder with abnormal

pathology. Diagnoses made by the consulting specialists in Houston were in agreement with those made by Army ocular specialists in Boulder. The conclusion reached by Krug was that remote ocular specialists can successfully utilize T1 communications systems to provide consultation to patients and practitioners that are medically or geographically isolated. NASA JSC's Medical Operations Branch is developing a network of medical consultants to provide support during space shuttle operations. Because T1 communications were very successfully using ACTS, T1 will be used to link NASA JSC to medical institutions for expert consultations. The information learned during the ACTS trial is also being applied to the design of a T1 telemedicine network to provide medical consultation to U.S. astronauts training in Russia.

National Library of Medicine (NLM) personnel are currently conducting tests using ACTS as a method to deliver medical data base information. The Laboratory for Radiological Information of the University of California at San Francisco is collaborating with NLM in this experiment.

A goal of modern medical information delivery is to create databases of important research and clinical data which are searchable using computer tools and interfaces. These modern medical databases include digital x-ray, magnetic resonance, computerized tomography and digital photography images. Some of the images are quite large - cervical x-rays about 5 megabytes; digital photographs are 7 megabytes and lumbar x-rays are 10 megabytes. Major data bases will most likely only be established at a few major medical sites around the country. Real time access by high speed links, such as the ACTS T1 links, will be necessary to satisfy the increasing demand for timely access to such databases. The NLM team is investigating bulk image file transfer using standard file transfer protocol (FTP) as well as transfer using NLM's "multi-socket" file transfer. Additional tests to evaluate the performance of particular client/server database applications are also planned.

The Lewis Research Center working with the Cleveland Clinic has investigated the use of ACTS T1 links for telemammography. Breast cancer is the most common cancer of American women; however, it is 90 percent curable if detected early. Mammography screening is believed to improve the date of diagnosis of breast cancer by two years. Due to certification requirements and economics, mammography experts are usually located in large medical facilities. People in rural, low population density areas generally have no direct access to such expertise. The NASA-Cleveland Clinic team is investigating the use of ACTS T1 links and data compression techniques to provide telemammography. The multiple views, the high resolution requirements and the need to compare current to previous images leads to a requirement of 320 megabytes of information. At a T1 rate (1.54 Mbps) it would take 27 minutes to transfer these images. Data compression techniques are being investigated to drastically reduce this total transmission time while still allowing for quality diagnosis.

The regulatory and legal issues associates with practicing medicine in "other" states, and collecting fees for telemedical services are just now beginning to be addressed. ACTS telemedical demonstrations to regulatory groups, insurance groups and lawmakers have demonstrated the readiness of the delivery of telemedical services on regional, national and global basis via satellites, and have underscored the urgency to address these other issues.

The on-demand flexible, high data rate transmission capabilities of the ACTS technologies could solve many medical outreach problems and provide better, cheaper health care to rural and under-served areas.

Military Applications

The modern battlefield will be dynamic and mobile. Operations require the tactical commanders to operate independently. To date, communications capabilities providing intelligence and command orders to these units has been limited to simple voice or low rate, narrow bandwidth communications. The Army Space Command is spearheading a number of Army organizations to evaluate the use of ACTS to provide tactical commanders with on-demand, wide bandwidth access to national and global networks. Six 1.2 meter, T1 VSATs have been ruggedized and configured to be highly transportable to support tactical operations. Objectives of this Army Program included (1) Identification future wideband satellite communications architecture requirements in support of all phases of Army operations and (2) provide relevant experience which will act as stepping stones for expanded Army use of wideband Milstar communications. In a number of operational field

trials and demonstrations with tactical units, ACTS is being used to allow integrated voice, video, data and imagery to be instantly transmitted to forward tactical units from diverse and geographically dispersed rear echelon commands. Tests to date have provide the local tactical commanders with control of large amounts of bandwidth (1.5 Mb) and the ability to dictate the assignment of this bandwidth. Key Army application have involved:

- video teleconferencing for command & control
- reconnaissance imagery
- data transfer
- tactical telephony network (MSE)
- integrated weather imagery/charts
- telemedicine
- logistics
- video conferencing for morale
- interconnection into Defense Commercial Telecommunications Network (DCTN) to provide a seamless satellite - terrestrial network.

The Army used their 7 T1 VSATs in support of Operation Uphold Democracy in Haiti. Figure 4 is a schematic of the ACTS network used to support this operation. Three T1 VSATs were located in Haiti while others were located at Ft. Bragg, North Carolina, Fort Drum, New York, and Army Space Command Headquarters in Colorado Springs, Colorado. At Fort Bragg, the T1 VSAT was connected into the Defense Commercial Teleconferencing Network. This connection allowed personnel in Haiti to video teleconference any military base in the world equipped with a DCTN node. Another important use of ACTS was the Army Mobile Subscriber Equipment (MSE) network. From the T1 VSAT at Fort Drum, a connection was made to the Dial Service Network. This capability expanded the field switching center capability in Haiti to full PBX interconnectivity in the U.S. Using the COMSAT T1 VSAT located in Clarksburg, Maryland, the Army connected to Walter Reed Medical Center in Washington, DC, via terrestrial lines and provided telemedicine support to Haiti.

In addition to the Haiti operations, the Space Command has conducted numerous other demonstrations and experiments in support of Army field exercises over the last two years. These Corps level tactical exercises have provided various units with a "hands-on" opportunity to use the ACTS System. From these tests and demonstrations the Army found that, (1) the 1.54 Mbps bandwidth allows local tactical commanders with greatly increased communication links over which they have direct control, (2) the 1.54 Mbps bandwidth allows video and high resolution imaging to be received in the field, (3) the 1.2 meter earth station with its tripod antenna mount and ruggedized electronics is easy to set up and transport for tactical operations, (4) the T1 VSAT user interface allows an interconnect with the Army's MSE providing expanded network capabilities and, (5) interconnecting into the public switched network and the Defense Commercial Teleconferencing network allows additional flexibility and versatility in interconnecting tactical units with rear echelon commands.

Such operational trials and demonstrations are allowing the Army to assess the use of the ACTS technologies to identify and evaluate tactical communications shortfalls as they develop their requirements for future wideband systems.

Network Restoral

Both the National Communications Systems (NCS) and Huntington Bank have conducted ACTS trials related to network restoral. These organizations investigated the use of the ACTS technologies to restoral communication services to support emergency operations.

One of the main functions of NCS is to provided low data rate (T1) communications restoral in emergency situations. To this end, NCS, NASA, the MITRE Corporation and JPL planned and executed a series of simulated emergency communications restoral tests using serveral T1 VSATs [12]. In performing the ACTS tests, terrestrial T1 connectivity between various locations were initially established than disrupted. Connectivity was reestablished via ACTS T1 VSATs. The ease of implementation as well as the effectiveness of such a system were key parameters under evaluation. Both full T1 (1.54Mbps) trunk and individual 64Kbps circuits were tested. Call prioritization software was developed and added to the ACTS network. With such prioritization higher priority callers could usurp communication channels from lower priority users. These tests proved highly successful. The experimenters concluded that the ACTS system provided high quality, consistent secure and clear voice communications. Further, it was possible to maintain data communications with a very low bit error rate. Establishing calls was easy and relatively efficient. Secure communication performed well at the 2.4, 4.8, and 9.6Kbps tested. Call prioritization

and remote personal identification number (PIN) also worked well.

Ohio University lead the Huntington Bank experiment designed to determine if satellite circuits were technically compatible with terrestrial transmission equipment and network management systems.[13] Full compatibility was found between the ACTS System and the terrestrial network. The ACTS T1 VSAT cold be integrated into Huntington Bank's T1 network in a straight forward manner without the need to develop special configurations for the terrestrial equipment. Circuit setup times on ACTS were within the range needed for redundant circuits; the times are comparable to, or better than on-demand terrestrial T1. No problems were found in the cutover to the ACTS circuits. The specific design of the ACTS T1 VSAT causes some minor incompatibilities in network management. Terrestrial T1 carrier networks use a low-speed, out-of-band channel to monitor T1 circuit equipment. ACTS currently does not support this channel. However, all in-band network management systems, such as those typically found in end-user T1 equipment, did function without any problems.

Protocol performance using SNA and SDLC, measured by end-user response time, was reduced on the satellite circuits as compared to the terrestrial link. This effect is to be expected considering the increased delay inherent in satellite transmissions coupled with SDLC polling requirements. In the case of the banking network, the resulting response time was about 1/3 of the terrestrial (about 1.5 vs 0.5 seconds). This level of performance is acceptable for a backup circuit and may not be acceptable for a redundant circuit depending on the circumstances.

Remote Observatory Access

ACTS T1 VSATs were installed at the Apache Point Observatory in Southern New Mexico and on the Campus of New Mexico State University (NMSU) [14] for trials in support of remote astronomy. ACTS provided a wideband T1 link to the observatory. This link allowed operations and control of the observatory facilities by remote users using the same interface as on-site observers. This trial allowed NMSU to test the ability of the remote interface to give the user a "touch and feel" for access and control. In this aspect, the real time nature of the link is critical to the safety of the 3.5 meter telescope as it is moved under remote control. A wideband channel is required to handle the data capacity needed from telescope such as this that produce a high-volume stream of data from an array of sensors. ACTS was also tested for non-real-time data networking to support observatory management, data base sharing, computer conferencing and similar services for the science community.

The experiment showed that the satellite link was a highly reliable means of delivering data from remote users around the U.S. From a real-time control point of view, the ACTS link has definite advantages over the Internet links being used. The ACTS one-way delay time (320 milliseconds) was actually less than that over the Internet and reasonably constant when compared with the Internet variability.

Others T1 VSAT User Trials

NBC used the T1 VSATs to transmit video between different fixed broadcast locations. Their experiment demonstrate that T1 and even sub T1 video and audio can be used in real time as contribution quality for Network News applications. In the future, broadcast news would be able to capture the story or event as its is happening. Live news anchors would be able to converse with reporters on scene and transmitted imagery would be of sufficient quality to be broadcast directly in real time into the network.

Amoco used T1 VSAT mounted on an oil platform in the Gulf of Mexico to transmit simulated seismic survey data to another T1 VSAT which was interfaced into the terrestrial network. Using ATM protocols and DS-3 (45 Mbps) rates, the 5 site network served as a model of the National Information Infrastructure. Collaborators at different sites around the U.S. were able to manipulate the simulated real-time data in their computers, exchange analyzed files and discuss analyses techniques and findings. In the future, the ability to get high data rate transmissions directly from seismic survey teams at sea or in the field will allow the information to be processed in real time while the acquisition is underway. Adjustments in field operations can be made in near real time in response to such data analysis - a significant change in the way business is conducted today. Amoco estimates that broadband networking can cut the exploration screening process from months down to hours.

Georgetown University along with University of Maryland, Cleveland State and Indiana

State Universities are working in collaboration with universities in Bogota, Colombia and Quito, Ecuador to develop and demonstrate the feasibility of distance education to foreign locations for business development as well as academic instruction.

Other ACTS application experiments included ISDN and frame relay. In addition numerous demonstrations have been conducted using the T1 VSATs. While these various user trials were being run, technical data on earth stations, network and BBP payload operations has been collected and is being analyzed.

General Conclusions - T1 VSAT Applications

- Small aperture earth stations are highly desired from a stand point of installation and transportation when this is necessary.
  - the 1.2 meter T1 VSAT can be located on ground, roof or pole mount
  - the Army routinely sets up their T1 VSATs in less than 2 hours

- T1 VSAT can operate in unattended fashion. Extends versatility to users with limited technical support.

- Voice quality over ACTS BBP is considered very good and satellite delay was not brought up as an issue by users.

- The Demand Assigned Multiple Access (DAMA) implemented in the ACTS network provides for circuit setup on the order of 10-12 seconds for regular telephone service and 3-8 seconds for ISDN.

- T1 VSAT is extremely versatile in providing a digital telephony interface at rates from 64 Kbps to 1.79 Mbps. Virtually any type of voice, video, data and multimedia user application hardware is compatible with the ACTS system.

- Direct connections into the terrestrial network enabled by T1 VSATs extend the versatility of ACTS tremendously. PSTN signaling protocols as well as ISDN and ATM protocols are supported.

- BER of the BBP services is very satisfactory.

- ACTS BBP network with its rain fade compensation operates well in poor weather.

- Availability of BBP service is determined primarily by T1 VSAT reliability. Rain outage was as expected.

- Users applaud the advantages of direct VSAT to VSAT (mesh) interconnectivity, the ability to control a large bandwidth - 1.8Mbps (24-64 Kbps) channels) the ability to mix and match 64 Kbps channels for high data rates and point-to-multipoint; multipoint to point networking capabilities.

FUTURE DIRECTIONS

Emphasis in the Experiments Program is shifting to the High Data Rate experiments as the HDR earth stations come on-line at experimenter sites. T1 VSAT application experiments will continue especially for organizations such as U.S. Army Space Command and National Communications System which own their own earth stations.

The T1 VSATs will support the distance education initiative of the Georgetown University Consortia to Universities in both Bogota Colombia and Quito Ecuador. LeRC engineers will focus their technology verification investigations on evaluating the network performance of the rain fade compensation algorithms as well as the measurement of the T1 VSAT service availability for a full complement of earth stations operating in the BBP network. Propagation measurements are funded for the third year of operations.

Spacecraft operators project that ACTS' stationkeeping fuel will be depleted in mid-1998 if present, full attitude stabilization and control operations are continued. If one north-south stationkeeping maneuver is deleted, approximately 30 months of additional fuel would be available to maintain east-west attitude control. Both LeRC and Lockheed Martin are examining the technical feasibility of included orbit operations on both the space and ground segments.

The number one challenge facing the satellite industry in the NII/GII falls under the banner of Standards and Interoperability to include:

1) universal access and universal service demand interoperability into seamless satellite-terrestrial networks,

2) terrestrial data standards and protocols which could preclude satellites from being included.

A satellite industry working group has been formed to look into these key standards and interoperabililty issues. Members include Hughes, Loral, AT&T, Motorola, TRW, Lockheed-Martin, COMSAT, and Harris. NASA will provide technical support to this working group. The ACTS system, spacecraft and earth stations, will provide the industry with a test bed platform with which to further characterize the performance of existing protocols and standards as well as test new and modified standards and protocols that are satellite friendly. This industry working group has formed into a number of subgroups to attack various aspects of the standards and interoperability issues. Specific ACTS experiments are being identified, planned and conducted as appropriate.

CONCLUSION

Satellites will play a key role in implementing a true Global Information Superhighway of seamless and agile satellite and terrestrial networks. ACTS is providing the technology bridge to achieve this vision. Through the ACTS Experiments Program, the basic technologies of the ACTS system are being characterized and validated. User trials with the ACTS test network are validating the use of all digital, on-demand, high bandwidth, integrated video, data, voice and other multimedia services for new, innovative and more cost effective user services.

The development, flight validation and user trials will allow industry to adapt the ACTS technologies to their individual commercial requirements at minimal risk. In facts, this is already happening. In the U.S., 14 communication satellite systems have filed with the FCC for U.S. domestic and international fixed satellite services from geostationary orbit - some 62 satellites. Additional filings have been made for non-geostationary fixed satellite services and feeder links for Big LEO systems. Internationally, 22 communication satellite systems filed with the ITU for international fixed satellite service involving more that 62 satellites.

ACTS has dramatically reduced the risk and created a high confidence in Ka-band, multiple beam and on-board switching and processing technologies among system providers, user, investors, manufacturers and insurers. ACTS has helped highlight the broad awareness of and the demand for new user service capabilities.

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